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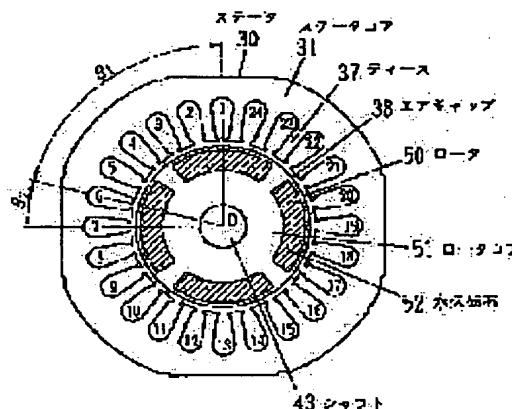
(54) BRUSHLESS DC MOTOR

(57)Abstract:

PROBLEM TO BE SOLVED: To make all the regions of field magnetic poles effective sections contributing to the torque by setting the open angle from the shaft center being opposed to the stator of magnet fields into a specific range.

SOLUTION: When the number of slots of a stator is twenty four, and the number of poles of the motor is four, the mechanical angle of the winding pitch per every phase and pole of each slot of the stator 30 is 75° , and the mechanical angle θ_2 of the slot pitch is 15° .

Besides, the pitch angle θ_1 of effective magnetic poles excluding zero regions out of a resultant magnetomotive force becomes a mechanical angle 75° . And if the rotor is rotated in the stator, interlinking magnetic flux changes, and a section where a peak induced voltage is generated is 120° by arm electric angle, and coincides with a conduction section 120° . But the total of the interlinking magnetic flux makes an approximately stepwise change, since the magnetic flux is deflected in an air gap 38. Accordingly, magnetic flux does not change very much, while the field magnetic poles having an open angle of $(\theta_1 - \theta_2)$ make one slot-pitch worth of move. As the result, it becomes possible to make all the regions of the field magnetic poles effective sections contributing to the torque.



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CLAIMS

[Claim(s)]

[Claim 1] It becomes a stator and this inside from Rota which carried out opposite arrangement through the air gap. Said stator equips with and constitutes the coil of the three-phase-circuit said alignment volume in the stator core which has two or more slots. In the brushless DC motor made to rotate said Rota by said Rota's equipped with and constituting a permanent magnet field in the shape of ** [core / rotor], and performing 120 degree energization of three phase circuits to said stator winding When theta 1 and the slot pitch angle of said slot are set to theta 2 for the pitch angle of the effective magnetic pole of the synthetic magnetomotive force produced with the coil of said stator by said energization, The brushless DC motor characterized by setting mostly the open angle from said stator of said permanent magnet field, and the rotation axial center which counters as the range of theta 1 to (theta1-theta2).

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Industrial Application] This invention relates to the brushless DC motor of the inner rotor mold equipped with the permanent magnet represented by the motor for a compressor drive of a refrigerator or an air-conditioning machine etc.

[0002]

[Description of the Prior Art] The general configuration of this kind of brushless DC motor is shown in drawing 10. As for this example, the number of slots of a stator shows the case where the pole of 24 and a motor is 4. While many teeth 37 exist in the inner circumference section of the stator core 31 of a stator 30, between each of these teeth, the slot shown with the slot number of 1-24 is established, and this slot is equipped with the coil which is not illustrated through an insulating material. Each slot is equipped with one coil of drawing 11 at a time, and they are arranged so that one pole of each phase may be formed with the coil 32 by which the said alignment volume was carried out by five slot pitches, so that the configuration of this coil may be shown and it may illustrate. U phase winding and an alternate long and short dash line 34 show V phase winding, and a broken line 35 shows W phase winding, respectively, and u, v, and w are ***** of U phase, V phase, and W phase, respectively, the neutral point when Y connection of 36 was carried out is shown, and, as for the drawing solid line 33, stator winding of three-phase-circuit 4 pole is constituted on the whole.

[0003] On the other hand, Rota 40 of drawing 10 consists of permanent magnets 42 with which it was equipped in the shape of ** [core / this / the rotor core 41, / rotor], and it is supported and constituted by the shaft 43 so that it may counter through the predetermined air gap 38 between the inner circumference sections of a stator core 31. A ferrite magnet or a rare earth magnet is used, four pieces of permanent magnets 42 are magnetized so that one piece of permanent magnet may form one pole, and they form a field.

[0004] Thus, in the constituted brushless DC motor, in each of the wave-like positive/negative of the induced voltage on the basis of the neutral point 36 of each phase generated by rotation of Rota 40, the energization to stator winding 32 energized 120 degree section of electrical angles before and after centering on a peak, and has acquired effective torque. This situation is shown in drawing 12. u1, v1, and w1 which are shown with a broken line in drawing are the example of an induced voltage wave when rotating Rota, and, generally it is a sine wave-like wave. Moreover, u2, v2, and w2 which are shown as a continuous line are an energization voltage waveform, and VN shows neutral point potential. When operating a motor by 120-degree energization, it is made into an energization field near the peak about the positive/negative [of an induced voltage wave] of each of each phase. That is, if I hear that that induced voltage is large has a large change of the magnetic flux interlinked to the coil of the phase, there is and change of magnetic flux passes a current to each phase in a large time domain, it will be a well-known fact that torque can be generated effectively.

[0005] Follow, for example, S5 carries out 120 degree section energization of electrical angles respectively with section S4 in the sections S1 and S2 and the negative direction in the forward direction in U phase. In V phase, it energizes [in / in the forward direction / in the section S3,

S4, and the negative direction / the sections S6 and S1 and W phase] to timing called the sections S2 and S3 by the sections S5 and S6 and the negative direction in the forward direction similarly. That is, two phases in a three-phase-circuit coil energize continuously, and rotation of Rota is made to maintain that it is also at the rotation magnetic pole in response to the angle of rotation of Rota, forming the pole of a predetermined pole.

[0006]

[Problem(s) to be Solved by the Invention] In the conventional brushless DC motor, as shown in drawing 10 , it is allotted in the pitch by which the number of field magnetic poles of the Rota 40 was made into the pole and the same number of a stator, is a pole and the division-into-equal-parts rate was carried out to the circumferential direction, therefore if the number of magnetic poles is set to P, the machine angle MP of the pitch is set to $Mp=360 \text{ degree}/P$, and, in the case of the field of four poles of drawing 10 , has become $Mp=90 \text{ degree}$.

[0007] On the other hand, since the said alignment volume of the coil which forms the magnetic pole by the side of a stator by energization is carried out by five slot pitch in the case of drawing 11 , the machine angle $\alpha 1$ of a winding pitch is 75 degrees. It seems that magnetomotive-force distribution of the magnetic pole in the case of drawing 11 is shown in drawing 13 when the energization turned to V phase for example, from U phase is made. In drawing 13 , the magnetomotive force according [(a)] to U phase winding, the magnetomotive force according [(b)] to V phase winding, and (c) show those synthetic magnetomotive force, respectively. In this case, although stator magnetic poles are four poles and that pitch is the 180 degrees (90 degrees of machine angles) of the same electrical angles as the pole pitch of Rota, if that distribution wave is seen, the actually effective field as a magnetic pole serves as the range of $\theta 1$ of 150 degrees of electrical angles (75 degrees of machine angles). That is, only the amount of [which is equivalent to the effective magnetic pole $\theta 1$ except a zero field among the synthetic magnetomotive force which is going to form one pole] pitch angle is an effective magnetic-flux field, and the stator teeth which this coil straddles in fact and are located inside serve as passage of magnetic flux.

[0008] If it is made to counter with the stator whose pitch of the effective magnetic pole of such synthetic magnetomotive force is 75 degrees and Rota whose pole pitch is 90 degrees of machine angles is rotated, a flux linkage will change like drawing 14 (a) per plane 1 of stator winding, and the induced voltage produced in this phase will become as it is shown in this drawing (b). Induced voltage generates peak induced voltage in the section $\alpha 2$ equal to the effective magnetic-flux field of a stator so that clearly from drawing 14 . However, the energization section is a total only of the 120-degree section of 60 degrees of electrical angles respectively before or after the peak induced voltage section to there being the section of this peak induced voltage between 150-degree (75 degrees of machine angles) divisions by the electrical angle. Therefore, 30 degree section of the difference is the un-effective section.

[0009] Conversely, the magnitude of the induced voltage in the anteposition phase which separated from the energization section requires the time amount for passing sufficient current deriving required torque, after starting energization, it produces the phase lag of the current over the applied voltage to a coil as a result, and worsens a power-factor. Since this is an electrical potential difference for the electrical potential difference of the difference of the electrical potential difference to impress and the induced voltage of the coil in the time to pass a current to the coil in the standup of the current after starting energization, a difference electrical potential difference for that induced voltage is large to raise a current becomes small as a result. Therefore, a current is in a phase with applied voltage, as a result of becoming the rise carried out slowly and the time amount which reaches a current value required for desired torque becoming long.

[0010]

[Means for Solving the Problem] This invention becomes a stator and this inside from Rota which carried out opposite arrangement through the air gap. Said stator equips with and constitutes the coil of the three-phase-circuit said alignment volume in the stator core which has two or more slots. In the brushless DC motor made to rotate said Rota by said Rota's equipped with and constituting a permanent magnet field in the shape of ** [core / rotor], and

performing 120 degree energization of three phase circuits to said stator winding When θ_1 and the slot pitch angle of said slot are set to θ_2 for the pitch angle of the effective magnetic pole of the synthetic magnetomotive force produced with the coil of said stator by said energization, The open angle from said stator of said permanent magnet field and the rotation axial center which counters is mostly set as the range of θ_1 to $(\theta_1 - \theta_2)$.

[0011]

[Function] The peak section of the induced voltage which the open angle of a field magnetic pole produces by change of the flux linkage to stator winding by this almost in accordance with the effective magnetic-flux field per pole of a stator turns into the effective section which all the fields of a field magnetic pole contribute to torque as a result in accordance with the energization section to stator winding, and futility does not arise. Moreover, by starting energization with an anteposition phase slightly [the section which generates the induced voltage of a peak], as for current ***** of the phase, torque comes to start quickly.

[0012]

[Example] Drawing 1 is the flat-surface sectional view of the brushless DC motor in which the example of this invention is shown, the number of slots of a stator shows the case where the pole of 24 and a motor is 4, like what was shown in drawing 10, and the sign same into a considerable part identically to drawing 9 is attached. Moreover, since the machine angle α_1 of the winding pitch of **** every pole is 75 degrees since the slot of 1-24 of the stator 30 in drawing 1 is equipped with the coil shown in drawing 11, and the number of slots is 24, the machine angle θ_2 of a slot pitch (= teeth pitch) is 15 degrees. Moreover, since the magnetomotive-force distribution by the coil of a stator is shown in drawing 13, the pitch angle θ_1 of the effective magnetic pole except a zero field is the 75 degrees (150 degrees of electrical angles) of the same machine angles as α_1 among the synthetic magnetomotive force which is going to form one pole. On the other hand, although the configuration of Rota 50 consists of permanent magnets 52 with which it was equipped in the shape of ** [core / this / the rotor core 51, / rotor] as shown in drawing 2, unlike the thing of drawing 10, the open angle θ_3 from the inner circumference section of the stator 30 of a permanent magnet 52 and the revolving-shaft alignment O which counters is the same 75 degrees as θ_1 .

[0013] If both θ_1 and θ_3 rotate Rota within a stator in the motor constituted at 75 degrees as mentioned above, a flux linkage will change like drawing 3 (a) per plane 1 of stator winding, and the induced voltage produced in this phase will become as it is shown in this drawing (b). In this case, it becomes 120 degrees (60 degrees of machine angles) by the electrical angle, all these sections α_3 turn into the effective section in accordance with 120 degrees of electrical angles which are the energization section, and futility does not produce the section α_3 which generates peak induced voltage so that clearly from drawing 3. Therefore, by energizing with an anteposition phase slightly [the section which generates the induced voltage of a peak], since induced voltage is low, a difference electrical potential difference with applied voltage becomes large, and its standup of a current is early.

[0014] It constituted from above-mentioned explanation so that it might become almost equal to the pitch angle θ_1 of the effective magnetic pole of the synthetic magnetomotive force which produces the open angle θ_3 of the permanent magnet field 52 of Rota 50 by stator winding 32, but even if θ_3 is less than [θ_1], the same effectiveness will be acquired if it is a certain fixed range. Namely, since the amount of the field magnetic flux which interlinks the situation of field magnetic flux in case the field pole of Rota moves to stator winding in proportion to migration does not change but magnetic flux is deflected in an air gap 38, the total of a flux linkage changes almost stair-like for every teeth pitch. Therefore, while field pole 52-a which has the open angle θ_3 as shown in drawing 4 ($\theta_1 - \theta_2$) moves by 1 slot pitch (= teeth pitch) to condition 52-c which exists in one edge of the range of θ_1 and which while will be condition 52-b Involved and exists in an edge, change of magnetic flux will be produced so much. Conversely, if it says, the part field pole equivalent to an include angle θ_2 may be small. Although the above explained the field with the permanent magnet, the same thing is obvious even if it is a coil field.

[0015] Moreover, although Rota 50 shown in drawing 2 has composition which embedded the

permanent magnet 52 in the rotor core 51, also in Rota of a configuration of having attached the permanent magnet in the periphery section of a rotor core, it is applicable [this invention] convenient at all in addition to this. Furthermore, in this invention, various permanent magnets can apply regardless of a configuration, and this point is explained a little below.

[0016] Rota 60 shown in drawing 5 embeds permanent magnets 62 and 63 at the hold hole of two or more V typefaces prepared in the rotor core 61, it is magnetized so that each of V typefaces each formed of the pair of each permanent magnets 62 and 63 may form one pole, and it forms the field of four poles on the whole. In the case of such Rota 60, it is referred to as theta 3 which defines the open angle from the stator of V characters of each pole, and the revolving-shaft alignment O of the field of the side which counters by this invention. Namely, what is necessary is just to set these theta 3 as the above-mentioned range of theta 1 to (theta1-theta2).

[0017] Rota 70 shown in drawing 6 is constituted by the permanent magnet 72 of four U typefaces which turned the convex to the inside, in such a case, sets the open angle of the stator side circular face of the permanent magnet 72 of U typeface to theta 3, and sets this as the include-angle range of this invention. Moreover, Rota 80 shown in drawing 7 arranges to multiplex the permanent magnet of U typeface shown in drawing 6 on each pole, it is magnetized so that one pole may be formed by the pair of the permanent magnets 82 and 83 of a duplex, and it forms the field of four poles on the whole. Since the outside permanent magnet 83 cannot enlarge an open angle on account of a tooth space in the case of such Rota 80, the open angle of the stator side circular face of the permanent magnet 82 arranged inside is set to theta 3, and this is set as the include-angle range of this invention. It is not limited to U typeface, and the permanent magnets 82 and 83 in Rota 80 of drawing 7 may be V typefaces, and they are not double and may be further constituted in multiplex.

[0018] Rota 90 shown in drawing 8 shows the case where it is constituted by the plate-like permanent magnet 92, in such a case, sets the open angle of the stator side straight-line side of the permanent magnet 92 of a cross-section rectangle to theta 3, and sets this as the include-angle range of this invention. In addition, 93 in drawing is the magnetic-flux short circuit prevention section, and it is stood in a row and prepared in the hold hole of the permanent magnet 92 prepared in the rotor core 91, and it forms by space or it is formed [inserts a non-magnetic material and].

[0019] Moreover, although it is common in the corner section of a permanent magnet that beveling parts, such as R beveling and C beveling, exist, the range of the open angle theta 3 shown in the above-mentioned example in such a case shall be appointed in general as follows. That is, as shown in drawing 8, let the open angle theta 3 of U characters constituted with the permanent magnet 73 which has the C beveling 74 and 74 at the edge of the field by the side of a stator be the open angle formed by the line of these C beveling 74 and 74 which connects the revolving-shaft alignment O to a pole Mabe approach edge most. This is because the effective section which can carry out outflow close to a rotator can come without saturating magnetic flux with a stator coil in this part since the width of face of the rotor core part between C beveling part and an air gap becomes large with this C beveling. Since it is the same, the same is said of the open angle theta 3 in the permanent magnet of V typeface which has C beveling, R beveling, etc. In addition, although the above example explained the motor of 4 pole structures, of course, this invention can contribute effectively to the thing of any poles, such as two poles and six poles.

[0020]

[Effect of the Invention] According to this invention, since it has secured by electrical degree width of face, compared with the same conventional motor as 120-degree energization which has the same capacity, field magnetic pole width of face can be made small for the peak induced voltage width of face of each phase. Therefore, the Rota weight can be reduced, the part permanent magnet which made especially the field pole pitch small can be made small, and reduction of components cost is made.

[0021] Moreover, since the peak induced voltage range considered as 120 degree range of electrical angles, in accordance with 120-degree energization section of stator winding, the

effective section which all the fields of a field magnetic pole contribute to torque as a result comes, and futility does not arise. Moreover, by starting energization with an anteposition phase slightly [the section which generates peak induced voltage], the current of the phase starts quickly, there are few current phase shifts to applied voltage, and the power-factor as a motor is improved as a result. moreover, the above — torque will also start quickly and the standup of a quick current does so the effectiveness that the torque ripple as a motor decreases.

[0022] If the thing in elegance is compared conventionally which was shown in the change and drawing 14 of the flux linkage to stator winding in this invention furthermore shown in drawing 3 , the situation of the change is equipped with the features of being hard to generate vibration and the sound which the thing of this invention is a thing near a smooth sine wave, therefore originate in flux reversal so that clearly.

[Translation done.]

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] The flat-surface sectional view of the brushless DC motor in which the example of this invention is shown.

[Drawing 2] The flat-surface sectional view of the Rota part of drawing 1 .

[Drawing 3] The wave form chart showing the change and induced voltage of the flux linkage per plane 1 in stator winding of the motor of drawing 1 .

[Drawing 4] The expansional mimetic diagram explaining a stator and the opposite condition of Rota.

[Drawing 5] The flat-surface sectional view showing another example of Rota of this invention.

[Drawing 6] The flat-surface sectional view showing still more nearly another example of Rota of this invention.

[Drawing 7] The flat-surface sectional view showing still more nearly another example of Rota of this invention.

[Drawing 8] The flat-surface sectional view showing still more nearly another example of Rota of this invention.

[Drawing 9] The explanatory view which illustrates beveling of a permanent magnet and the relation of an open angle.

[Drawing 10] The flat-surface sectional view of the brushless DC motor in which the conventional example is shown.

[Drawing 11] Drawing 1 and the expansional mimetic diagram of stator winding in the motor of drawing 10 .

[Drawing 12] The wave form chart showing the induced voltage and the energization electrical potential difference of stator winding.

[Drawing 13] It is a magnetomotive-force distribution map at the time of the U-V energization in stator winding of drawing 11 , and what depends (a) on U phase winding, the thing which depends (b) on V phase winding, and (c) show those synthetic magnetomotive force.

[Drawing 14] The wave form chart showing the change and induced voltage of the flux linkage per plane 1 in stator winding of the motor of drawing 10 .

[Description of Notations]

1-24 Slot

30 Stator

31 Stator Core

32 Stator Winding

33 U Phase Winding

34 V Phase Winding

35 W Phase Winding

36 Neutral Point

37 Teeth

38 Air Gap

40, 50, 60, 70, 80, 90 Rota

41, 51, 61, 71, 81, 91 Rotor core

42, 52, 62, 63, 72, 73, 82, 83, 92 Permanent magnet
43 Shaft

[Translation done.]

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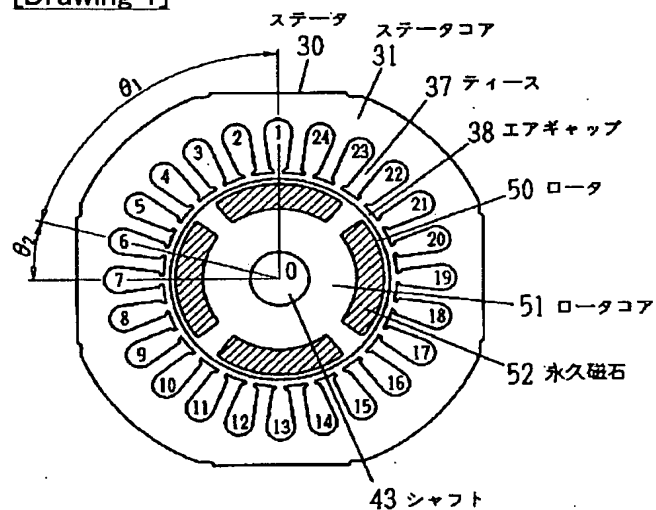
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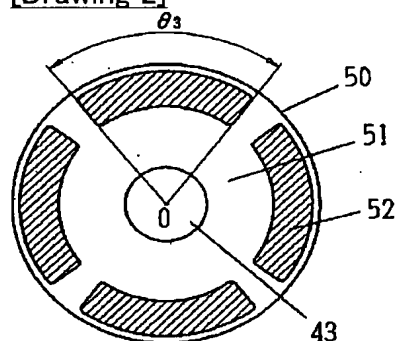
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DRAWINGS

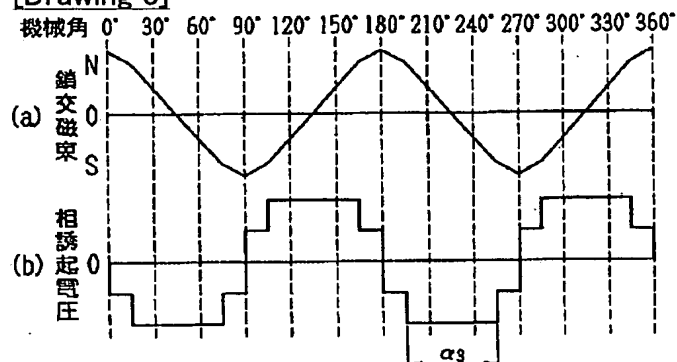
[Drawing 1]



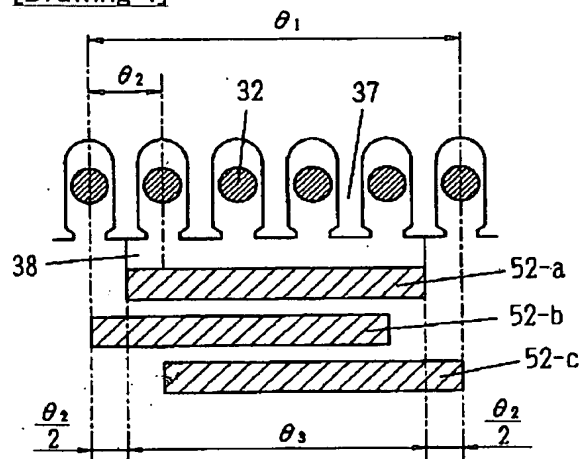
[Drawing 2]



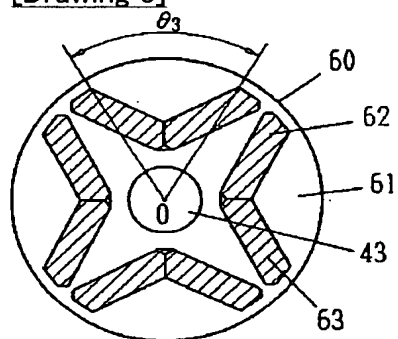
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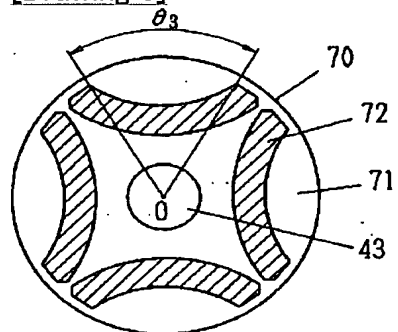
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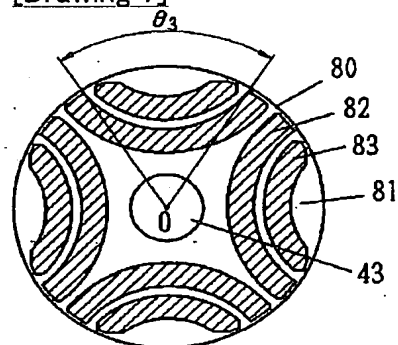
[Drawing 5]



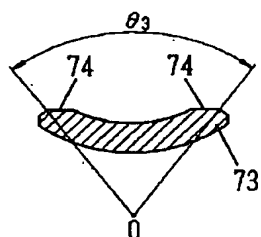
[Drawing 6]



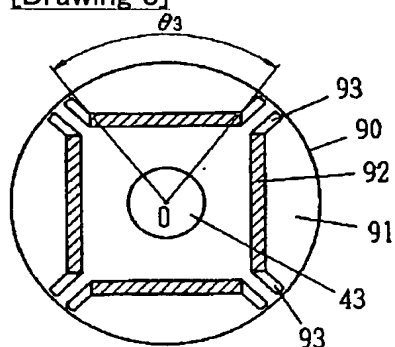
[Drawing 7]



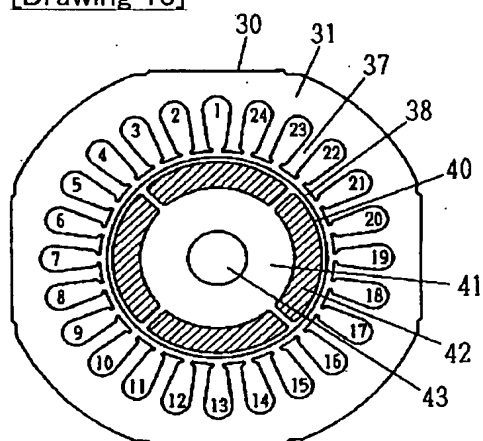
[Drawing 9]



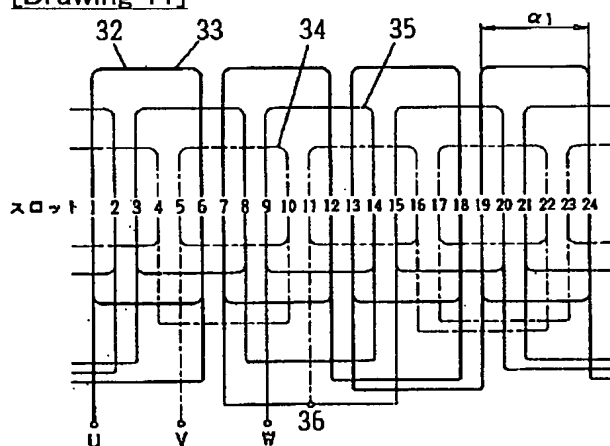
[Drawing 8]



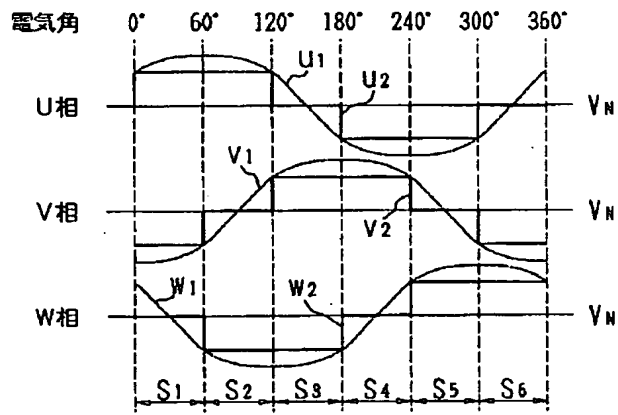
[Drawing 10]



[Drawing 11]

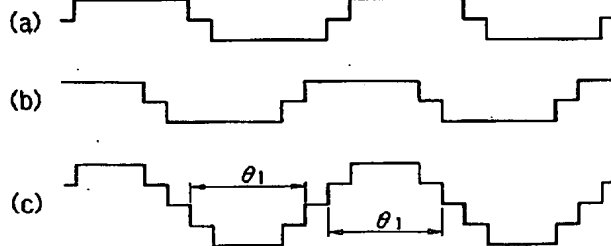


[Drawing 12]

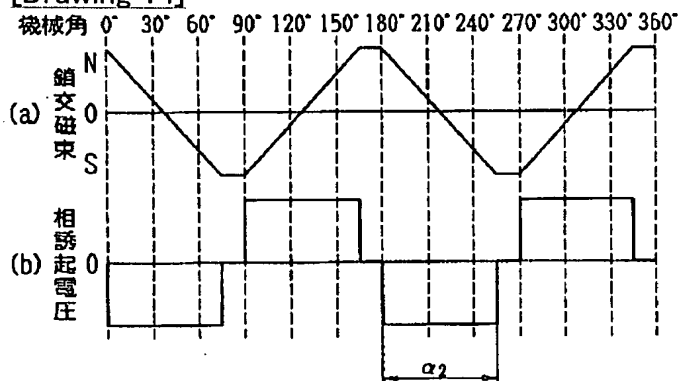


[Drawing 13]

スロット 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24



[Drawing 14]



[Translation done.]

(43)公開日 平成10年(1998)1月16日

M

ステータ
ステータコア
30
31
37 ティース
38 エアギャップ
50 ロータ
51 ロータコア
52 永久磁石
43 シャフト
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 θ_1
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(2)

特開平10-14190

【特許請求の範囲】

【請求項1】 ステータとこの内側にエアギャップを介して対向配置させたロータよりなり、前記ステータは複数のスロットを有するステータコアに3相同心巻きの巻線を装着して構成し、前記ロータはロータコアに等配状に永久磁石界磁を装着して構成し、前記ステータ巻線に3相120°通電を行うことによって前記ロータを回転させるブラシレスDCモータにおいて、前記通電によって前記ステータの巻線によって生じる合成起磁力の有効磁極のピッチ角を $\theta 1$ 、前記スロットのスロットピッチ角を $\theta 2$ としたとき、前記永久磁石界磁の前記ステータと対向する回転軸心からの開角をほぼ $\theta 1$ から $(\theta 1 - \theta 2)$ の範囲に設定したことを特徴とするブラシレスDCモータ。

【発明の詳細な説明】

【0001】

【産業上の利用分野】本発明は冷凍機や空調機の圧縮機駆動用モータ等に代表される永久磁石を装着したインナーロータ型のブラシレスDCモータに関する。

【0002】

【従来の技術】この種のブラシレスDCモータの一般的な構成を図10に示す。この例はステータのスロット数が24、モータの極数が4の場合を示している。ステータ30のステータコア31の内周部には多数のティース37が存在するとともに、この各ティース間には1〜24のスロット番号にて示すスロットが設けてあり、このスロットには絶縁物を介して図示しない巻線が装着されている。図11はこの巻線の構成を示すものであり、図示するように、各スロットには1コイルずつ装着されており、5スロットピッチで同心巻きされた巻線32によって各相の1つの極を形成するように配置されている。図中実線33はU相巻線、一点鎖線34はV相巻線、破線35はW相巻線をそれぞれ示し、またu、v、wはそれぞれU相、V相、W相の口出部であり、36はY結線された中性点を示し、全体で3相4極のステータ巻線が構成されている。

【0003】一方、図10のロータ40は、ロータコア41とこのロータコアに等配状に装着された永久磁石42とで構成され、ステータコア31の内周部との間に所定のエアギャップ38を介して対向するようにシャフト43によって支持されて構成される。4片の永久磁石42は、フェライト磁石あるいは希土類磁石等が用いられ、1片の永久磁石が1極を形成するように着磁されて界磁を形成するようになっている。

【0004】このように構成されたブラシレスDCモータにおいて、ステータ巻線32への通電は、ロータ40の回転によって発生する各相の中性点36を基準とする誘起電圧の波形の正負の各々において、ピークを中心とする前後の電気角120°区間を通電して有効なトルクを得ている。この様子を図12に示す。図において破線

で示すu1、v1、w1はロータを回転させた時の誘起電圧波形の例であり、一般的に正弦波状の波形である。また実線で示すu2、v2、w2は通電電圧波形であり、VNは中性点電位を示している。モータを120°通電で運転する場合は、各相の誘起電圧波形の正負各々についてピーク近傍を通電領域にする。即ち、誘起電圧が大きいということは、その相の巻線に鎖交する磁束の変化が大きいということであり、磁束の変化が大きい時間領域で各相に電流を流せば効果的にトルクを発生させることができることは周知の事実である。

【0005】従って、例えばU相においては正方向では区間S1とS2、負方向では区間S4とS5の各々電気角120°区間通電し、同様にV相においては正方向では区間S3とS4、負方向では区間S6とS1、W相においては正方向では区間S5とS6、負方向では区間S2とS3といったタイミングで通電を行う。即ち、絶えず3相巻線内の2相が通電されて、所定の極数の極を形成しつつロータの回転角に呼応した回転磁極でもってロータの回転を維持せしめている。

【0006】

【発明が解決しようとする課題】従来のブラシレスDCモータでは図10に示されるように、そのロータ40の界磁磁極数はステータの極数と同数とされ、円周方向に極数で等分割されたピッチで配されており、従ってそのピッチの機械角MPは、磁極数をPとすると、 $Mp = 360^\circ / P$ となり、図10の4極の界磁の場合 $Mp = 90^\circ$ となっている。

【0007】一方、通電によりステータ側の磁極を形成する巻線は、図11の場合5スロットピッチで同心巻きされているので巻線ピッチの機械角 $\alpha 1$ は75°となっている。図11の場合における磁極の起磁力分布は、例えばU相からV相へ向けた通電がなされると図13に示すようなものとなる。図13において(a)はU相巻線による起磁力、(b)はV相巻線による起磁力、(c)はそれらの合成起磁力をそれぞれ示している。この場合、ステータ磁極は4極であってそのピッチはロータの磁極ピッチと同じ電気角180°(機械角90°)であるが、その分布波形をみると実際に磁極として有効な領域は電気角150°(機械角75°)の $\theta 1$ の範囲となっている。即ち1極を形成しようとする合成起磁力のうち零領域を除く有効磁極 $\theta 1$ に相当するピッチ角分のみが有効磁束領域であり、実際にはこの巻線の跨り内に位置するステータティースが磁束の流路となっている。

【0008】このような合成起磁力の有効磁極のピッチが75°のステータと対向させて磁極ピッチが機械角90°のロータを回転させると、ステータ巻線の1相当たり図14(a)のように鎖交磁束が変化し、この相に生じる誘起電圧は同図(b)のようになる。図14から明らかなように、誘起電圧は、ステータの有効磁束領域に等しい区間 $\alpha 2$ でピーク誘起電圧を発生する。ところが

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このピーク誘起電圧の区間は電気角で 150° （機械角 75° ）区間あるのに対し、通電区間はピーク誘起電圧区間の前後各々電気角 60° の合計 120° の区間のみである。従ってその差 30° 区間は非有効区間である。

【0009】逆に通電区間を外れた前位相での誘起電圧の大きさは、通電を開始してから必要なトルクを導出するに十分な電流を流すための時間がかかり、結果として巻線への印加電圧に対する電流の位相遅れを生じさせて力率を悪化させる。これは、通電を開始してから電流の立ち上がりにおいては、印加する電圧とその時点での巻線の誘起電圧との差分の電圧がその巻線へ電流を流すための電圧であるので、誘起電圧が大きいうことは電流を上昇させるための差電圧が結果として小さくなる。従って電流はゆっくりとした上昇となり、所望のトルクに必要な電流値に達する時間が長くなる結果、印加電圧との位相が遅れるのである。

【0010】

【課題を解決するための手段】本発明は、ステータとこの内側にエアギャップを介して対向配置させたロータよりなり、前記ステータは複数のスロットを有するステータコアに3相同心巻きの巻線を装着して構成し、前記ロータはロータコアに等配状に永久磁石界磁を装着して構成し、前記ステータ巻線に3相 120° 通電を行うことによって前記ロータを回転させるブラシレスDCモータにおいて、前記通電によって前記ステータの巻線によって生じる合成起磁力の有効磁極のピッチ角を θ_1 、前記スロットのスロットピッチ角を θ_2 としたとき、前記永久磁石界磁の前記ステータと対向する回転軸心からの開角をほぼ θ_1 から $(\theta_1 - \theta_2)$ の範囲に設定したものである。

【0011】

【作用】界磁磁極の開角がステータの1極当たりの有効磁束領域とほぼ一致し、これによりステータ巻線への鎖交磁束の変化によって生じる誘起電圧のピーク区間がステータ巻線への通電区間と一致し、この結果界磁磁極のすべての領域がトルクに寄与する有効区間となって無駄が生じない。またピークの誘起電圧を発生する区間のわずかに前位相で通電を開始することにより、その相の電流ひいてはトルクが素早く立ち上がるようになる。

【0012】

【実施例】図1は本発明の実施例を示すブラシレスDCモータの平面断面図であり、図10に示したものの同様ステータのスロット数が24、モータの極数が4の場合を示しており、図9と同一または相当部分には同一の符号が付してある。また図1におけるステータ30の1～24のスロットには、図11に示す巻線が装着されるため、毎相毎極の巻線ピッチの機械角 α_1 は 75° であり、またスロット数が24であるためスロットピッチ（＝ティースピッチ）の機械角 θ_2 は 15° となっている。また、ステータの巻線による起磁力分布は図13に

示すようになっているので、1極を形成しようとする合成起磁力のうち零領域を除く有効磁極のピッチ角 θ_1 は α_1 と同じ機械角 75° （電気角 150° ）となっている。一方、ロータ50の構成は、図2に示すようにロータコア51とこのロータコアに等配状に装着された永久磁石52とで構成されるが、図10のものと異なり、永久磁石52のステータ30の内周部と対向する回転軸心Oからの開角 θ_3 は、 θ_1 と同じ 75° となっている。

【0013】上記のように θ_1 と θ_3 が共に 75° に構成したモータにおいて、ステータ内でロータを回転させると、ステータ巻線の1相当り図3(a)のように鎖交磁束が変化し、この相に生じる誘起電圧は同図(b)のようになる。この場合図3から明らかなように、ピーク誘起電圧を発生する区間 α_3 は電気角で 120° （機械角 60° ）となり、通電区間である電気角 120° と一致し、この区間 α_3 のすべてが有効区間となって無駄が生じない。従って、ピークの誘起電圧を発生する区間のわずかに前位相で通電することにより、誘起電圧は低いので印加電圧との差電圧が大きくなり電流の立ち上がりが早い。

【0014】上記の説明では、ロータ50の永久磁石界磁52の開角 θ_3 をステータ巻線32によって生じる合成起磁力の有効磁極のピッチ角 θ_1 とほぼ等しくなるように構成したが、 θ_3 が θ_1 以下であっても、ある一定の範囲であれば同様の効果が得られるものである。即ち、ロータの界磁極が移動する場合の界磁磁束の様子は、移動に比例してステータ巻線に鎖交する界磁磁束の量が変化するのではなく、エアギャップ38の中で磁束が偏向されるため、鎖交磁束のトータルはティースピッチ毎にほぼ階段状に変化する。従って図4に示すように、 $(\theta_1 - \theta_2)$ なる開角 θ_3 を有する界磁極52-aは、 θ_1 の範囲の一方の端部に存在する状態52-bからもう一方の端部に存在する状態52-cまで1スロットピッチ（＝ティースピッチ）分移動する間は磁束の変化はさほど生じないことになる。逆に言えば、角度 θ_2 に相当する分界磁極が小さくてもよいことになる。以上は界磁を永久磁石で説明したが、巻線界磁であっても同様であることは自明である。

【0015】また図2に示したロータ50はロータコア51内に永久磁石52を埋め込んだ構成となっているが、これ以外に、ロータコアの外周部に永久磁石を取り付けた構成のロータにおいても本発明は何等支障なく適用可能である。さらに本発明においては、種々の永久磁石が形状を問わず適用可能であり、この点について以下若干説明する。

【0016】図5に示すロータ60は、ロータコア61に設けた複数のV字形の収容孔に永久磁石62、63を埋め込んだものであり、各永久磁石62、63のペアによって形成される各V字形のそれぞれが1極を形成するように着磁されて、全体で4極の界磁を形成している。

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このようなロータ60の場合、各極のV字のステータと対向する側の面の回転軸心Oからの開角を本発明で定義する $\theta 3$ とする。即ち、この $\theta 3$ を前述の $\theta 1$ から($\theta 1 - \theta 2$)の範囲に設定すればよい。

【0017】図6に示すロータ70は、凸面を内側へ向けた4つのU字形の永久磁石72によって構成されており、このような場合は、U字形の永久磁石72のステータ側円弧面の開角を $\theta 3$ とし、これを本発明の角度範囲に設定する。また図7に示すロータ80は、図6に示したU字形の永久磁石を各極において多重に配置したものであり、2重の永久磁石82、83のペアによって1極を形成するように着磁されて、全体で4極の界磁を形成している。このようなロータ80の場合、外側の永久磁石83はスペースの都合上開角を大きくできないため、内側に配置された永久磁石82のステータ側円弧面の開角を $\theta 3$ とし、これを本発明の角度範囲に設定する。図7のロータ80における永久磁石82、83はU字形に限定されるものではなくV字形であってもよく、また2重ではなくさらに多重に構成してもよい。

【0018】図8に示すロータ90は、平板状の永久磁石92によって構成された場合を示しており、このような場合は、断面長方形の永久磁石92のステータ側直線面の開角を $\theta 3$ とし、これを本発明の角度範囲に設定する。尚、図中93は磁束短絡防止部であり、ロータコア91に設けられた永久磁石92の収容孔に連なって設けてあり、空間によって形成したりあるいは非磁性材料を挿入して形成される。

【0019】また永久磁石のコーナー部にはR面取りやC面取り等の面取り部分が存在するのが一般的であるが、このような場合における上記実施例に示す開角 $\theta 3$ の範囲は概ね次のように定めるものとする。即ち、図8に示すようにステータ側の面の端部にC面取り74、74を有する永久磁石73により構成されるU字の開角 $\theta 3$ は、このC面取り74、74の最も極間部寄り端部と回転軸心Oとを結ぶ線により形成される開角とする。これは、このC面取りによって、C面取り部分とエアギャップとの間の回転子鉄心部分の幅が大きくなるために、この部分においては固定子コイルによる磁束が飽和することなく回転子に流出入できる有効な区間になり得るからである。同じ理由から、C面取りやR面取り等を有するV字形の永久磁石における開角 $\theta 3$ についても同様である。尚、以上の実施例では4極構造のモータに関して説明したが、2極や6極等いかなる極数のものに対しても本発明は有効に寄与し得ることは勿論である。

【0020】

【発明の効果】本発明によれば、各相のピーク誘起電圧幅を 120° 通電と同じ電気角度幅分確保しているのので、同一能力を有する従来のモータと比べて界磁磁極幅を小さくすることができる。従ってロータ重量を削減でき、特に界磁磁極ピッチを小さくした分永久磁石を小さ

くすることができて部品コストの削減がなされる。

【0021】またピーク誘起電圧範囲が電気角 120° 範囲としたので、ステータ巻線の 120° 通電区間と一致し、この結果界磁磁極のすべての領域がトルクに寄与する有効区間となって無駄が生じない。またピーク誘起電圧を発生する区間のわずかに前位相で通電を開始することにより、その相の電流が素早く立ち上がり、印加電圧に対する電流位相のずれが少なく、結果としてモータとしての力率が改善される。また上記素早い電流の立ち上がりは、トルクも素早く立ち上がることになり、モータとしてのトルクリプルが少なくなるといった効果を奏する。

【0022】さらに図3に示した本発明におけるステータ巻線への鎖交磁束の変化と図14に示した従来品におけるものとを比較すると明らかなように、その変化の様子は本発明のものが滑らかな正弦波に近いものとなり、従って磁束変化に起因する振動や音が発生しにくいといった特長を備えている。

【図面の簡単な説明】

【図1】本発明の実施例を示すブラシレスDCモータの平面断面図。

【図2】図1のロータ部分の平面断面図。

【図3】図1のモータのステータ巻線における1相当たりの鎖交磁束の変化と誘起電圧を示す波形図。

【図4】ステータとロータの対向状態を説明する展開模式図。

【図5】本発明のロータの別の実施例を示す平面断面図。

【図6】本発明のロータのさらに別の実施例を示す平面断面図。

【図7】本発明のロータのさらに別の実施例を示す平面断面図。

【図8】本発明のロータのさらに別の実施例を示す平面断面図。

【図9】永久磁石の面取りと開角の関係を例示する説明図。

【図10】従来例を示すブラシレスDCモータの平面断面図。

【図11】図1及び図10のモータにおけるステータ巻線の展開模式図。

【図12】ステータ巻線の誘起電圧と通電電圧を示す波形図。

【図13】図11のステータ巻線におけるU-V通電時の起磁力分布図であり、(a)はU相巻線によるもの、(b)はV相巻線によるもの、(c)はそれらの合成起磁力を示す。

【図14】図10のモータのステータ巻線における1相当たりの鎖交磁束の変化と誘起電圧を示す波形図。

【符号の説明】

1～24 スロット

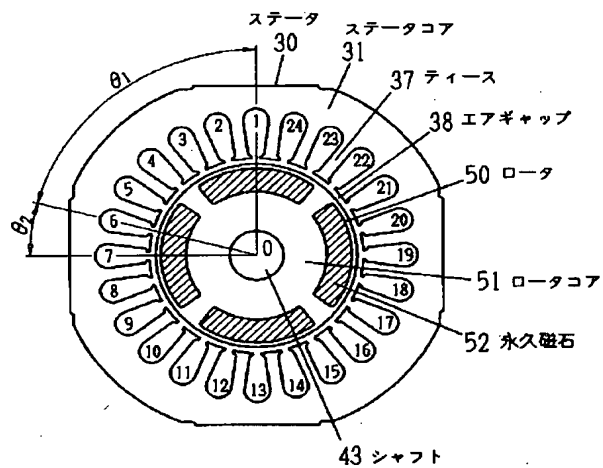
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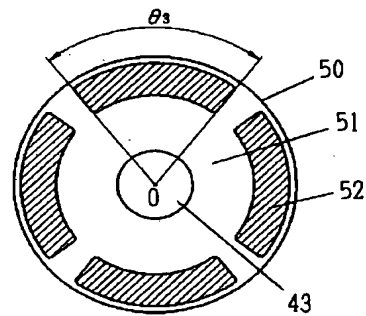
30 ステータ
31 ステータコア
32 ステータ巻線
33 U相巻線
34 V相巻線
35 W相巻線
36 中性点

37 ティース
38 エアギャップ
40, 50, 60, 70, 80, 90 ロータ
41, 51, 61, 71, 81, 91 ロータコア
42, 52, 62, 63, 72, 73, 82, 83, 9
2 永久磁石
43 シャフト

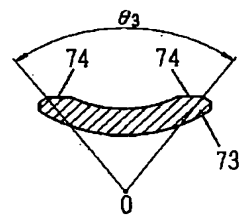
【図1】



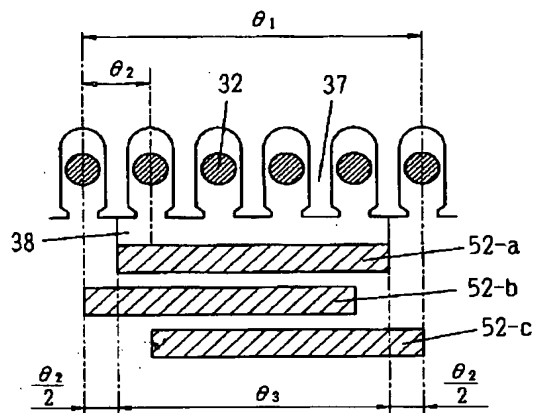
【図2】



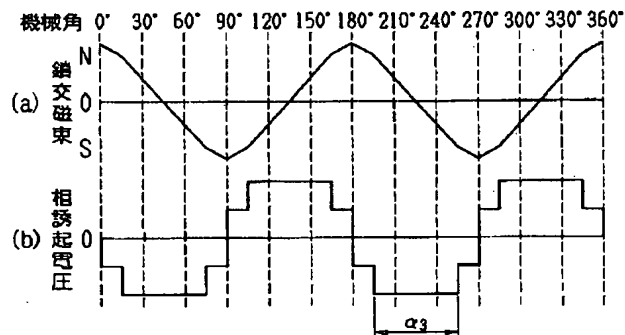
【図9】



【図4】

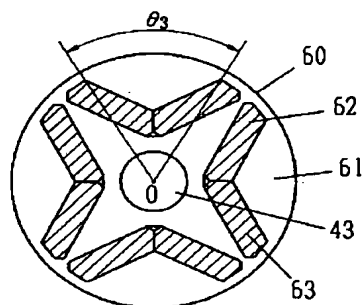


【図3】

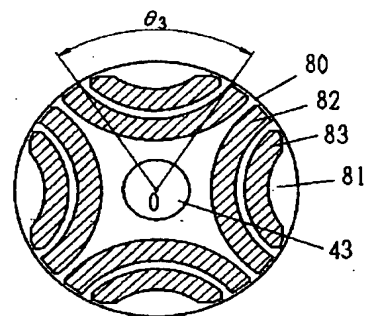
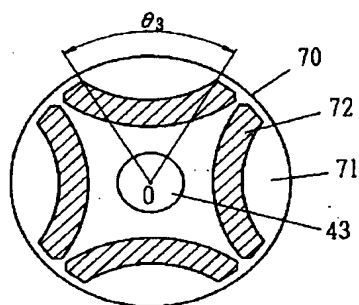


【図7】

【図5】



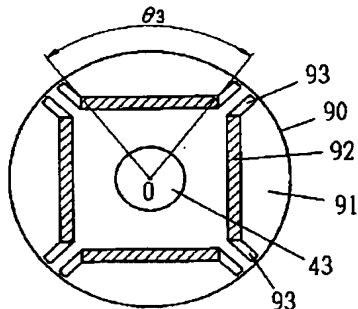
【図6】



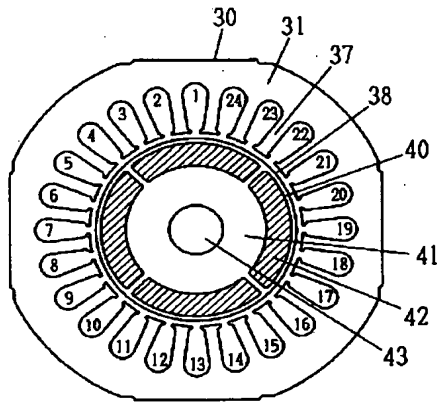
(6)

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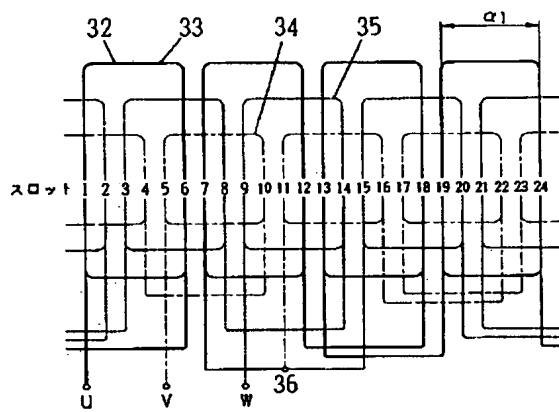
【図8】



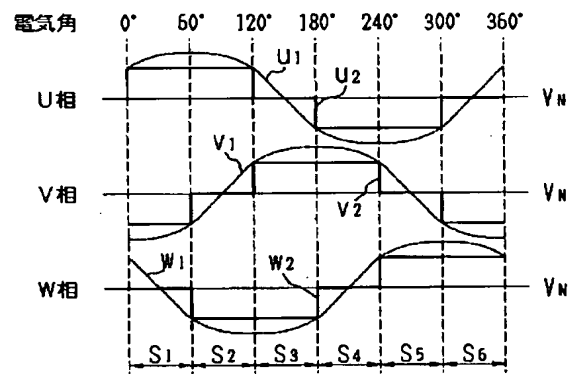
【図10】



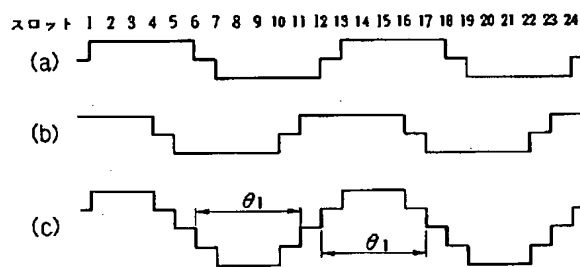
【図11】



【図12】



【図13】



【図14】

